Trip Report
Next Generation Navigation System Tests

Who: Ric Walker, U.S. Coast Guard Research and Development Center

When: Jan 22-24, 2002

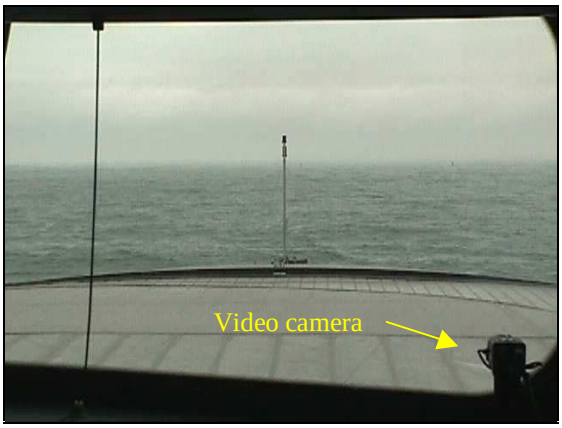
Where: Morehead City, NC

Why: Operational testing of prototype Augmented Reality (AR) Navigation System

Summary: The AR Nav system was installed aboard a high-speed catamaran for operational testing during a Joint Task Force Exercise (Jan 15 –24, 2002). Coast Guard RDC staff evaluated the performance of the system as a navigational aid and the Navy evaluated its performance for tracking AUVs, display of operational boundaries, and mine-laying operations. The system requirements for these two functions were very similar. The overall results were very positive. The system displayed several types of navigation information, which were useful to the OOD/Helmsman and Navigator. The display integrated a forward-looking video camera image and virtual navigation information for an enhanced navigation picture. The horizontal view complimented the bird's-eye view provided by the radar and electronic chart system. Users found the system had increased value in reduced visibility and night operations. Test results and user feedback provided critical input for next steps in system improvement and integration.

Background The Coast Guard has partnered with Naval Warfare Development Command (NWDC) to develop a new navigation and operational picture display system using augmented reality technology. The current system prototype, called **A**ugmented **R**eality **V**isualization of the **C**ommon **O**perational **P**icture (**ARVCOP**) by the Navy, was subjected to its second operational test during this Joint Task Force Exercise (JTFX). Technology Systems, Inc of Wiscassett, ME is the contractor responsible for system development. The platform for this exercise was the HSV-X1 *Joint Venture*, a 96m wave-piercing catamaran. The vessel was a very stable platform capable of speeds up to 48kt. The Navy evaluated the ARVCOP system in support of mine-laying operations, and for tracking assets such as unmanned surface vehicles and autonomous underwater vehicles. These tests were conducted during the period 15-23 Jan, 2002. The navy crew operating the vessel also used ARVCOP in the navigation mode during numerous harbor transits. The original schedule was to ride the vessel on Jan 23-24 to evaluate the performance of the system as a navigational aid. Poor weather limited the opportunity for underway evaluation to Jan 23 only. During that time I was able to observe the system being used for navigation as the vessel transited Morehead City harbor at the beginning and end of the day, and in the ARVCOP mode in coastal waters for several hours during the day.

System and Installation The prototype AR AtoN system consists of a forward-looking video camera, a GPS receiver, laptop computer, electronics interface box, and a display monitor. The system also required input from the ship's digital gyrocompass. All equipment was installed on the bridge for this test. The video camera was mounted on the dash looking forward and had a 90^0 field of view. The display monitor was mounted on the starboard side counter, next to the navigator's station. The laptop and electronics box was mounted under the counter.



Forward view showing video camera

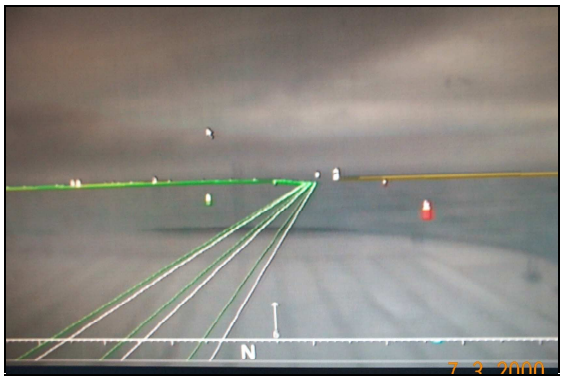
AR display next to navigator's station

AR AtoN laptop and interface box under counter.

AR installation on HSV bridge

System performance Four types of navigation information were presented on the AR AtoN display:

- lanes
- aids to navigation
  (buoys and daymarks/lighthouses)
- shoreline
- ship's heading.



For this exercise, all physical features were based on data extracted manually from a nautical chart. The lanes were defined and entered in the Navy's **M**ine warfare and **E**nvironmental **D**ecision **A**ids **L**ibrary (MEDAL) database, and then transferred to the AR AtoN computer. The registration of the AR icons relative to the real world features on the composite video image was quite good. The low-lying land features registered very well. The icons for the floating aids marking the harbor channel generally appeared slightly inboard of the actual channel marks with some consistency. The icons for fixed aids actually overlaid the real objects in many cases. The heading was taken directly from the ship's gyro, and presented as a strip along the bottom of the image.

The ARVCOP system presented Navy operational information for the exercise such as:

- lanes,
- exercise operational boundaries
- submerged object locations
- AUV tracks.

The AR display was useful to both the helmsman and the navigator, but the relative importance they placed on this presentation varied with the mission. During mine laying operations, the helmsman used ARVCOP as the principle navigation source to maintain a straight track using the virtual lane presentation. The helmsman also used the AR AtoN cues with greater frequency during harbor approach. The helmsman relied primarily on the short range aids while navigating inside the harbor.

ARVCOP displayed the complete programmed track of the AUV mission including the point at which the vehicle was programmed to surface for pickup. Observers on the bridge using ARVCOP spotted the vehicle using the AR cues before the small boat and were able to vector them in, reducing the overall recovery time.

The system was quite reliable during the 8-day test period and experienced only minor problems. The system failed after initial installation due to a new, but faulty, cable connector. This was easily fixed with a new cable. There was also a minor problem with the digital gyro interface, which was resolved with a few keystrokes. Otherwise the system performed without problems.

The AR system video image was very fuzzy due to signal losses from converting the analog camera image to digital format. The image degraded further when the CRT monitor was replaced by a flat panel LCD screen to save counter space.

Another problem with the display was that it was difficult to resolve multiple objects at long range, and their icons tend to "stack" on horizon. Multiple AR objects on the same relative bearing may also overlay each other depending on the separation distance and icon size. On the positive side, the AR icons' size increased with decreasing range, which improved the users ability to identify the object and added realism to the display.

Benefits to navigation users The AR system horizontal view is natural and intuitive, and compliments the plan view from charts and radar. This type of display does not require the mental translation from a plan presentation to real world (horizontal) view out the window. Users found the system more useful at night and in low visibility. Users reported that the AR display improved their ability to detect and identify aids at night that were normally hard to find in heavy background lighting. Users also found the AR aids and shoreline features gave them a greater sense of confidence when operating in reduced visibility due to rain and fog. Locating the harbor entrance in the low-lying barrier beach was also easier with the AR display.

System improvements. These operational tests have revealed several aspects of the prototype system that require improvement.

- The poor quality of the video image should be addressed by developing an all-digital system (ONR may fund this)
- The system should be integrated with other NavAids such as radar, ECDIS/ECS, using the standard NEMA interface. This would allow additional functionality, such as target ID and sharing and waypoint selection and plotting (e.g. select an aid or other target on ECDIS or radar and it gets highlighted on AR system view)
- The location of the AR display was not optimal for the helmsman during this test. It would be better to locate it nearer to the helmsman and closely aligned with his normal field of view for rapid correlation of real-world and AR display views. One possibility is centered in the overhead electronics panel. Another possibility is to design a shared display with one of the other system monitors. It might be desireable to toggle with ECDIS/ECS and/or radar displays in such a way that both the navigator and helmsman could have the AR display whenever they selected it on their own monitor

- The system should be able to interface with CG's Aids to Navigation Information System (ATONIS) database for official aid position data, and tested to identify any potential problems.
- The problem of distant AR information stacking on the horizon may be addressed by adding a full simulation mode in which the user invokes an elevated view (selects height of eye) to resolve objects "stacked" on horizon. The system would return to the video image base when the height of eye returns to normal.

Recommendations. I recommend that we continue the development of the AR AtoN system in partnership with the Navy. The partnership is mutually beneficial and our continued participation ensures CG design goals will be addressed. The next steps in development will be based on the system improvements described above. At the same time we should identify CG performance gaps that can be addressed by this technology, and identify internal customers that can assist in advancing the design in a way that best addresses these performance shortfalls.

RTW
2/6/02